Student Discovery Journal
How Plants Work: A Guide to Being Green

Welcome to the United States Botanic Garden's *How Plants Work* Exhibit!

Jump right in and explore the giant, interactive plant models and the many living plant examples. As you wander through the exhibit you will learn how you are both similar to and different from your green partners!

What characteristics do you think something has to have in order to be considered "alive"? Do plants fall into this category? Although they don't move around, plants are as alive as you are. In the *How Plants Work* Exhibit, explore the following 5 'Big Ideas' to learn how plants are alive and how plants function. The 5 'Big Idea' topics you'll be asked to investigate are:

1) Are Plants Like Us?
2) A Puzzle of Plant Parts
3) The Green Machine
4) Surviving Against the Odds
5) Plant Multiplication

As you study the 5 'Big Ideas' in the *How Plants Work* Exhibit, you'll be asked to venture into the Conservatory. While trekking through the different habitats, you will discover living examples of how plants work and see each 'Big Idea' in action.

Sometimes you might see a *Think Tank!* box. When you see one of these boxes, discuss the questions with your group and write your responses in the space provided.

The pages that follow and the activities you will do form your Discovery Journal. Feel free write down questions as you go. If you don't find the answers here, look them up or ask a teacher when returning to school.

Ready to discover how plants work?

Let's get started!

(Insert botanical-themed graphics)

Are Plants Like Us?

Do you really grow like a weed?

(Insert clip art of various kinds of plants, including jungle vines, orchids, ferns and cacti – should frame page and be consistent throughout this section)

Explore the Exhibit…

Investigate the "Are Plants Like Us?" Exhibit area.

Think Tank! How are humans and plants the same? How are they different?

Become a Savvy Plant Sleuth!

Follow your teacher or chaperone into the Plant Exploration Room in the Conservatory.

For this activity, you will need a partner.

Look around at all the different plants in the Plant Exploration Room. Choose any plant and compare it to your partner.

What plant did you choose? Why? _____

_____

Looking at your partner and your plant choice, answer the following questions in the space provided:

List 3 things both the plant *and* your partner can do (Example: eat):

1. _____
2. _____
3. _____

List 3 things the plant can do that your *partner cannot* do (Example: make oxygen):

1. _____
2. _____
3. _____

List 3 things your partner can do that the *plant cannot* do (Example: walk around):

1. _____
2. _____
3. _____

Be prepared to share these responses!

Dig Deeper…
You be the Botanist!

The United States Botanic Garden needs your help developing hypotheses about how plants use light, water, and nutrients. Use what you learned in the *How Plants Work* Exhibit, along with your eyes and brain, to create your hypotheses. There is no right answer, so get thinking!

[Insert Vocabulary Box – Hypothesis: A tentative explanation for an observation, phenomenon, or scientific problem that can be tested by further investigation.]

Follow your teacher or chaperone up the Catwalk in the Jungle. Look at all the epiphytes in the surrounding trees. Choose one epiphyte and draw it in the space below:

[Insert Vocabulary Box – Epiphyte: A plant that grows on top of, or is attached to, another living plant without being a parasite.]

Plant Name **Plant Family**

Think Tank! How do epiphytes get light? How do they get water? How do they get nutrients?

[Insert magnifying glass clip art & the following: Pay close attention to the roots of the epiphytes! What makes them special?]

Write your hypothesis about epiphyte light, water, or nutrient use in the space below:

Follow your teacher or chaperone to the World Deserts Room. Look at the different cacti. Choose one cactus you think is fun and draw it in the space below.

Plant Name

Plant Family

Think Tank!
How do cacti get light? How do they get water? How do they get nutrients?

[Insert magnifying glass clip art & the following: Pay close attention to the skins and stems of the cacti! Do these plants look different than the ones in the Jungle?]

Write your hypothesis about cactus light, water, or nutrient use in the space below:

Think back to these hypotheses as you explore and investigate how plants work.

What Did You Learn?
Follow your teacher or chaperone back to the *How Plants Work* Exhibit.

Think Tank!
Consider the following statement:
Plants are like humans because both need energy to survive. However, plants are different because they create their own energy from the sun and can make their own food. Is this statement true or false? Why?

A Puzzle of Plant Parts:
Why do plants have so many different parts?

(Insert around the corners of these pages drawings (or photographs) of interesting looking roots, stems, leaves, flowers, fruits, and seeds. Possible options include: a fig leaf next to a fern leaf next to at hawthorn branch and a root (carrot?) or one of each coming in from each corner of the pages – should frame page and be consistent throughout this section)

Explore the Exhibit…
Investigate the "A Puzzle of Plant Parts" Exhibit area.

Think Tank!
Look at the large plant sculpture *Scarlet magnifica*. What major plant parts are highlighted? What job does each part play?

[Insert puzzle piece clip art & the following: Part Puzzle Piece #1: STEMS!]
Look at the drawing below and at the stem of *Scarlet magnifica*. What do the Green and Blue cords represent? Label them on the drawing below:

*(Insert cropped, non-labeled version of stem artwork from HPW gallery [cross-section of Scarlet magnifica's stem]-**provided above**)*

Become a Savvy Plant Sleuth!
Follow your teacher or chaperone into the Garden Court.

[Insert puzzle piece clip art & the following: Part Puzzle Piece #2: LEAVES!]
Search through a few of the plants in the Garden Court. Find 2 plants with COMPLETELY DIFFERENT leaves. Look at leaf shape, color, and texture to find differences. Draw each leaf in the space provided, making sure to write down the name of the plant it belongs to!

Plant Name **Plant Family**

Plant Name **Plant Family**

Think Tank! What influences the size of a plant's leaves?

[Insert puzzle piece clip art & the following: Part Puzzle Piece #3: ROOTS!]
Follow your teacher or chaperone to the Orchid Room.

Look up, down, and all around. Find a plant that has roots above ground. Draw both the plant you found and its surrounding habitat in the space below.

Plant Name

Plant Family

Think Tank!
Why do you think these plants have roots above ground? If you were searching the world for plants with roots above ground, where would you look? Why?

[Insert puzzle piece clip art & the following: Part Puzzle Piece #4: FLOWERS!]
Stay in the Orchid Room, but this time look at all the different flowers. Find your favorite flower and draw it in the space below.

Plant Name

Plant Family

Think Tank!
Why do some plants have flowers?

Dig Deeper…
Follow your teacher or chaperone back to the Garden Court.

Use your knowledge of plant parts to explore the Garden Court and complete this chart:

Find a plant that humans depend on for something they drink. Which part of the plant is used in this drink?		
Plant:	Product:	Plant Part:
Find and list below two plants with parts that are used to season and flavor foods and/or drinks. What part of that plant do you use?		
Plant:	Plant Part:	
Look at the large murals. Find a plant that is used to make a product that you didn't know came from plants. What part of the plant does this item come from?		
Plant:	Product:	Plant Part:

What Did You Learn?
Follow your teacher or chaperone back to the *How Plants Work* Exhibit.

Think Tank!
Consider the following statement:
Plants and animals are both living things but their parts function differently to allow them to cope with the challenges in their environments.
Is this statement true or false? Why?

The Green Machine

How is a plant like a machine?

(Insert drawings or photographs viewing plant structures & cells from under a microscope – should frame page and be consistent throughout this section)

Explore the Exhibit…

Investigate the "Green Machine" Exhibit area.

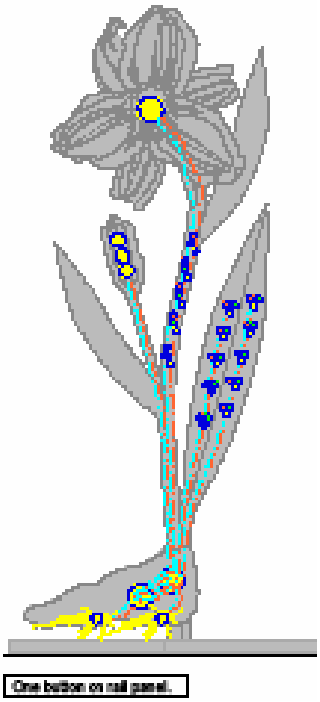
With your group, gather around the large plant sculpture *Electra botanica*. Take turns pushing the buttons that cause the plant sculpture to light up.

Think Tank! Why does *Electra botanica* light up? What do all the different colored lights represent?

To help you remember all the activities that happen when a plant makes energy, first find the "Leaves and Stems" and "Roots" labels by *Electra*. Then draw a line to connect the activity description with the light activity represented on the large sculpture.

Water movement (*water flow*)

Carbon dioxide bonds with remaining Hydrogen ions to form simple sugars energized by ATP (*energy flow*



Chlorophyll molecules capture light energy and carry out photosynthesis (*energy flow*)

Sugars converted to starch (storage) and cellulose (building tissue) (*energy flow*)

This is not a great image – could an outline drawing of the sculpture be re-created? Or just make this image better by importing/placing it using a different technique?
(link=G:Conservatory:Conservatory Room Descriptions:East Gallery:PRD (East Gallery):Ex-4.6.pdf)

[Insert Vocabulary Box – Photosynthesis: The process a plant uses to change light energy, minerals, enzymes, and chlorophyll into food.*]
[Insert Vocabulary Box – Chlorophyll: The main pigment that collects the energy of sunlight in green plants.*]
[Insert Vocabulary Box – Cellulose: Carbohydrate that is the primary material in the cell walls of plants.]
Insert Vocabulary Box – Chloroplast: An organelle inside a plant cell that contains chlorophyll and captures energy from the sun.*]
[Insert Vocabulary Box – ATP: "adenosine triphosphate" – The primary vehicle for energy storage and energy exchange in a cell.]
*these definitions are from the Fairchild Tropical Botanic Garden "Green Machine" Vocabulary List – retrieved on 3/18/08 from
http://www.fairchildgarden.org/uploads/docs/Education/teacher%20training/green%20machines/Green%20Machines%20Vocabulary.pdf

Think Tank!
Talk with your group. How does *Electra botanica's* Green Machine work? (Draw or list thoughts below.)

Take a moment to look at the walls in the *How Plants Work* Exhibit. The photos on the wall are what you would see if you looked at plants through an Electron Microscope. Find the photos of the Christmas Rose Leaf and the Horsetail Stem.

[Insert Vocabulary Box – Electron Microscope: An instrument that uses electrons instead of light to view very tiny objects invisible to the naked eye (e.g. cells in plants).]

[Insert magnifying glass clip art & the following: What parts of the Christmas Rose Leaf and the Horsetail Stem are visible? How might these parts help the plant's green machine?]

Think Tank!
What can Electron Microscope photos tell you about plant energy production? Do you think they are helpful? Why or why not?

Become a Savvy Plant Sleuth!
Follow your teacher or chaperone to the Jungle in the Conservatory.

Explore the Jungle. Find a plant you enjoy. Draw a picture of it below.

Plant Name

Plant Family

Now, using what you just saw in the Electron Microscope photos, take an imaginary X-ray of your plant. Draw your plant's X-ray in the space below. Be sure to label the plant systems like the Green Machine example *Electra* and point out the main parts that help the plant to run smoothly.

Think Tank!
Think about your plant's energy source. What fuels your plant's Green Machine?

Now examine a leaf on your plant (or on another plant if your plant is not at eye level). Get real close! Below, draw what your leaf would look like if you were viewing it through an Electron Microscope. Then think back to *Electra botanica* and try to list the leaf parts that are the sun's energy receivers. (Example: chloroplasts)

Think Tank!
Talk with your group. What are the products of photosynthesis?

Dig Deeper…
Follow your teacher or chaperone back to the *How Plants Work* Exhibit.

Think Tank!
How is the way that plants create and use energy different from the way humans get, use, and produce energy?

What Did You Learn?

Think Tank!
Both you and plants contain a variety of systems to ensure growth. How do plants use their "green machines" to make and use their own food?

Surviving Against the Odds

How do plants adapt and survive?

(Insert a drawing or photograph of a cactus in one corner and a vine system in an opposing corner – should frame page and be consistent throughout this section)

Explore the Exhibit…

Investigate the "Surviving Against the Odds" Exhibit area.

Think Tank!

Why do plants need adaptations?

Complete the following chart, listing examples of each type of plant adaptation.

Adaptation	**Plant Example**
Physical	
Growth Pattern	
Physiological	
Plant-Animal Partnership	

[Insert Vocabulary Box – Physiological: A characteristic relating to the normal, healthy functioning of an organism.]

Think Tank!

Which adaptation interests you the most? Why?

If you'd like, sketch your favorite adaptation too!

Become a Savvy Plant Sleuth!
Be an Explorer!

Think Tank!
Consider the following statement:
Plants only have so much energy so they need to make good use of it. Adaptations take energy to create, so each one of these characteristics has a specific function.
Work with your group to brainstorm one or two adaptations a plant may want to have in the Jungle. Why would it be worth using the plant's energy to have the adaptations you chose?

The United States Botanic Garden would like your help in charting different plant adaptations in our Conservatory. Follow your teacher or chaperone on a Scavenger Hunt and fill in the chart below.

Adaptive Trait	**Plant**	**Country of Origin**	**Why you chose it**
A plant that looks like it could stop herbivores from eating it.			
A plant with flowers that are arranged in clusters.			
A plant with leaves that appear to be chewed.			
A plant with aerial roots.			
Two different plants with leaves made to thrive in a very rainy environment.			
A plant that appears to depend upon another plant for survival.			

A plant that has characteristics to help protect it from the hot desert sun.			

From where your Scavenger Hunt ends, follow your teacher or chaperone through the World Deserts Room and the Garden Primeval to return to the *How Plants Work* Exhibit.

As you are walking, look at the plants you pass. Consider how each plant is specially suited for its environment.

Think Tank!
What are the major differences between plants growing in the World Deserts Room and plants growing in the Garden Primeval?

Dig Deeper…
Think about your own experiences adapting to your environment. Talk with your group and come up with different ways you adapt to various weather conditions. List your answers below.

What do **YOU** do if it is…			
Wet?	Windy?	Hot?	Cold?

Now consider what a plant would do in the same conditions. List your answers below.

What does **A PLANT** do if it is…			
Wet?	Windy?	Hot?	Cold?

Think Tank!
Think about yourself, where you live, and someone who is a friend. If you could create any adaptation for yourself or your friends, what would you do? If you could create any adaptation for a plant in your schoolyard, what would you do?

Choose your favorite of the adaptations you just created. In the space below, draw your choice. Be prepared to explain why it is important and how it works to make life better for the organism for which it was designed.

What Did You Learn?

Think Tank!
Why do plants need adaptations? Could plants survive without certain adaptations? Why or why not?

Plant Multiplication

How do plants reproduce?

(Insert photo or drawing of a flower, the underside of a fern leaf to show spores, and/or a cone bearing plant – should frame page and be consistent throughout this section)

Explore the Exhibit…

Investigate the "Plant Multiplication" Exhibit area.

Depending on your teacher or chaperone instructions, do one of the following in the space below:

Option 1: Examine each section of the "Plant Multiplication" Exhibit area and become an expert on 1 plant group that interests you. In the space below, draw an example from your chosen plant group and list a few of its special reproductive characteristics.

OR

Option 2: Your class will be divided into 4 groups. Each group will be assigned 1 of the 4 major plant groups. Your group should become experts on your designated plant group. In the space below, draw 1 or more examples from your plant group and list its special reproductive characteristics.

Be prepared to share your findings!

Become a Savvy Plant Sleuth!
Follow your teacher or chaperone into the Medicinal Plants Room.

Explore the gallery space and find a flower in the process of turning into a fruit. Sketch your selection in the space below.

Plant Name

Plant Family

Think Tank!
Talk with your group. What happens to plants before and after flowering?

Follow your teacher or chaperone to the Garden Primeval.

Explore the various plants.

[Insert magnifying glass clip art & the following: Look carefully. Do you see any flowers in this room?]

Think Tank!
Which of the 4 major plant groups are represented in this section of the Conservatory?

Examine several ferns and look for sori. See if you can find moss with sporophytes. If you see moss with sporophytes, draw them below.

[Insert Vocabulary Box – Sori: Small, circular, rust-colored patches on the underside of fern blades that release spores for reproduction.]
[Insert Vocabulary Box – Sporophyte: Spore-producing phase in the life cycle of a plant.]

Think Tank!
How do sori help ferns reproduce? What do sporophytes do to help moss reproduce? Was it difficult to find moss with sporophytes? Why or why not?

[Insert magnifying glass clip art & the following: Do you see the Brontosaurus?]

There is a dinosaur that lives in the United States Botanic Garden's Garden Primeval. Can you find him? If you have time, draw him in the space below.

Think about why the dinosaur was placed in the Garden Primeval section of the Conservatory.

Think Tank!
How did ferns and mosses survive while the dinosaurs became extinct?

Dig Deeper…
Follow your teacher or chaperone back to the *How Plants Work* Exhibit.

Find the Plant Family Tree. With your group, discuss how the plant family tree is divided. Where is the major plant group you chose or were assigned?

Think Tank!
Looking at the Plant Family Tree, which plant group is the largest? How might your new knowledge about plant multiplication help you figure out why one plant group family is larger than another?

What Did You Learn?

Think Tank!
Consider the following statement:
Plants, like animals, must reproduce and create offspring to ensure species survival. However, unlike animals, plants cannot travel around to find mates.

What reproductive strategies do plants use for survival? Is any strategy better than any other? If so, which one? If not, why?

Review: What have you learned?

Big Idea 1:
Plants are like you because you both need energy to survive. How are you different from a plant?

Big Idea 2:
Plants are comprised of a number of parts which all work together to help them survive in and benefit from their surroundings. What are the different plant parts? How do they work together to use energy from the sun? How do they get water and nutrients from the soil to survive where they are planted?

Big Idea 3:
Both you and plants contain a variety of systems to ensure growth. How do plants use their "green machines" to make and use their own food?

Big Idea 4:
If you are cold you put on a sweater to fight off a chill. How do plants thrive in the many different temperature, light, moisture, and soil type conditions found on the planet?

Big Idea 5:
To ensure species survival, plants, like you, must reproduce and create offspring. Unlike you, plants cannot travel around to find their mates. How do plants reproduce?

(Insert botanical-themed graphics that were used on the introductory page of this journal)